

# **SEMICONDUCTOR DEVICE AND METHOD FOR CONTROLLING THE SAME**

## **BACKGROUND OF THE INVENTION**

5        This application claims the priority of Korean Patent Application No. 10-2003-0055014 filed on August 8, 2003, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference.

### **1. Field of the Invention**

10        The present invention relates to a semiconductor device, and more particularly, to a semiconductor device and method for controlling the same, which is capable of reducing data write errors by rewriting last write data during a write recovery time (tWR).

### **2. Description of the Related Art**

15        In general, a write recovery time (tWR) is defined as a time until a read or write operation is enabled after a previous write operation of a semiconductor device, that is, the time period when last data are written to when a pre-charge command signal is input.

20        Particularly, the write recovery time (tWR) is represented by the number of clocks, such as by  $tWR = 2 \text{ clocks}$  or  $tWR = 3 \text{ clocks}$ , in synchronous semiconductor devices, for example, a Synchronous Dynamic Random Access Memory (SDRAM), or a Double Data Rate Synchronous Dynamic Random Access Memory (DDR SDRAM), and particularly, is several or more clocks in higher speed synchronous semiconductor devices.

      Conventionally, as there is a risk of erroneous operation when read or write operations are performed under the state that the semiconductor devices do not secure sufficient write recovery time (tWR), memory cell arrays for storing write data voltages and write drivers for supplying the write data voltages are electrically separated from each other.

25        Accordingly, the conventional semiconductor devices are supplied with the write data voltages only through column lines connected to the memory cell arrays during the write recovery time (tWR).

      In conventional semiconductor devices, however, the write recovery time (tWR)

should be lengthened in order to sufficiently supply a last write data voltage for the memory cell arrays. If that is not done, there is a risk of the occurrence of errors in the last data write, particularly if the last write data conflict with stored data.

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## SUMMARY OF THE INVENTION

A feature of the present invention is to provide a semiconductor device, which is capable of sufficiently supplying last data voltage to memory cell arrays by repeatedly activating only a column line into which the last data are written during a write recovery time (tWR).

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According to one aspect of the present invention, there is provided a semiconductor device, comprising: a memory cell array having a plurality of cell units; a bit line amplifier for amplifying a voltage difference between a bit line voltage and a complementary bit line voltage of the memory cell array; switching devices activated by a column selection line signal for electrically connecting a data line and a complementary data line to the bit line and the complementary bit line, respectively; and a write driver for supplying a write data voltage to the data line and the complementary data line, wherein the column selection line signal is generated during a write recovery time.

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In one embodiment, the column selection line signal is repetitively generated during the write recovery time.

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In one embodiment, the semiconductor device further comprises a signal generator for generating the column selection line signal, wherein the signal generator is activated by a signal derived from an AND operation of an AND gate with respect to a column selection line enable signal and a column address selection signal activated by a column address signal and is deactivated by a column selection line disable signal, for generating the column selection line signal.

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In one embodiment, the column selection disable signal is generated after the column selection line enable signal is generated.

In one embodiment, the column selection line disable signal is generated with a delay

by at least half of the period of the column selection line enable signal, compared to the column selection line enable signal.

In one embodiment, the signal generator comprises: a first PMOS transistor into which a signal derived from an AND operation of an AND gate with respect to the column selection line enable signal and the column address selection signal is input; an NMOS transistor into which the signal derived from the AND operation of the AND gate with respect to the column selection line enable signal and the column address selection signal is input; a second PMOS transistor connected between the first PMOS transistor and the NMOS transistor and into which an inverted signal of the column selection line disable signal is input; and an inverter connected to a point between the second PMOS transistor and the NMOS transistor.

In one embodiment, the signal generator further comprises a second inverter connected to the inverter via a latch.

In one embodiment, the column selection line enable signal is generated by an AND operation of an AND gate with respect to the write enable signal and a master clock signal.

In one embodiment, the column selection line disable signal is generated by an AND operation of an AND gate with respect to the master clock signal after a predetermined delay time and the write enable signal activated by an inverted signal of the master clock signal.

In one embodiment, the semiconductor device further comprises a signal generator for generating the write enable signal, wherein the signal generator is activated by a write command signal and is deactivated by a stop signal of a column address burst counter.

In one embodiment, the signal generator comprises: a first NOR gate into which the write command signal is input; a second NOR gate connected to the first NOR gate via a latch and into which the stop signal of the column address burst counter is input; and an inverter connected to an output terminal of the first NOR gate.

In one embodiment, the stop signal of the column address burst counter is generated with a delay by at least one clock of a master clock signal after a start of the write recovery time.

In one embodiment, the stop signal of the column address burst counter is generated

with a delay in proportion to a value of the write recovery time.

In one embodiment, the stop signal of the column address burst counter is activated by a write recovery time enable signal.

5 In one embodiment, the semiconductor device further comprises a signal generator for generating the write recovery time enable signal, wherein the signal generator comprises: a PMOS transistor into which an inverted signal of a write recovery time determination signal is input; an NMOS transistor into which the inverted signal of the write recovery time determination signal is input; a fuse connected between the PMOS transistor and the NMOS transistor; and an inverter connected to a connection point between the fuse and the NMOS  
10 transistor.

In one embodiment, the signal generator further comprises a second inverter connected to the inverter via a latch.

In one embodiment, an internal column address signal is generated after the column address signal is generated after a predetermined delay time.

15 In one embodiment, the column address signal is reset by the stop signal of the column address burst counter.

In one embodiment, the column address signal is activated by a column address set signal and is generated after the predetermined delay time.

In one embodiment, the column address signal is activated by a signal derived from an  
20 AND operation of an AND gate with respect to the master clock signal and an inverted signal of the column address set signal and the internal column address signal is generated.

In one embodiment, the column address signal is generated during at least one clock of the master clock signal after a start of the write recovery time.

In one embodiment, the column address signal is generated in proportion to a value of  
25 the write recovery time.

In one embodiment, the column address set signal is activated by the write enable signal and is deactivated after a predetermined delay time.

According to another aspect of the present invention, there is provided a method of

controlling a semiconductor device including a memory cell array consisting of a plurality of cell units, a bit line amplifier for amplifying a voltage difference between a bit line voltage and a complementary bit line voltage of the memory cell array, switching devices activated by a column selection line signal for electrically connecting a data line and a complementary data line to the bit line and the complementary bit line, respectively, and a write driver for supplying a write data voltage to the data line and the complementary data line. The method includes the steps of: writing data voltage into the memory cell array and generating the column selection line signal during a write recovery time.

In one embodiment, the step of generating the column selection line signal includes generating the column selection line signal repetitively.

In one embodiment, the step of generating the column selection line signal includes activating the column selection line signal using the write enable signal.

In one embodiment, the step of generating the column selection line signal includes generating the write enable signal during at least one clock of a master clock signal after a start of the write recovery time.

In one embodiment, the step of generating the column selection line signal includes generating the write enable signal in proportion to a value of the write recovery time.

In one embodiment, the step of generating the column selection line signal includes deactivating the write enable signal using a stop signal of a column address burst counter.

In one embodiment, the step of generating the column selection line signal includes generating the stop signal of the column address burst counter with a delay by at least one clock of the master clock signal after the start of the write recovery time.

In one embodiment, the step of generating the column selection line signal includes generating the stop signal of the column address burst counter in proportion to a value of the write recovery time.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features and advantages of the invention will be

apparent from the more particular description of a preferred embodiment of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

5        FIG. 1 is a block diagram showing a conventional semiconductor device.

FIG. 2 is a circuit diagram showing a counter controller of the conventional semiconductor device.

FIG. 3 is a timing diagram showing a write operation of the conventional semiconductor device (in the case of  $t_{WR}=2$  clocks).

10        FIG. 4 is a block diagram illustrating a semiconductor device according to an embodiment of the present invention.

FIG. 5 is a circuit diagram illustrating an enable and disable signal generator for a column selection line signal in a semiconductor device according to an embodiment of the present invention.

15        FIG. 6 is a circuit diagram illustrating a command signal controller in a semiconductor device according to an embodiment of the present invention.

FIG. 7 is a circuit diagram illustrating a column address buffer in a semiconductor device according to an embodiment of the present invention.

20        FIG. 8 is a circuit diagram illustrating a main decoder in a semiconductor device according to an embodiment of the present invention.

FIG. 9 is a circuit diagram illustrating a column address set signal generator in a semiconductor device according to an embodiment of the present invention.

FIG. 10 is a circuit diagram illustrating a counter controller in a semiconductor device according to an embodiment of the present invention.

25        FIG. 11 is a circuit diagram illustrating a write recovery time enable signal generator in a semiconductor device according to an embodiment of the present invention.

FIG. 12 is a timing diagram showing a write operation of a semiconductor device (in the case of  $t_{WR}=2$  clocks) according to an embodiment of the present invention.

## DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 is a block diagram showing a conventional semiconductor device. As shown in FIG. 1, a semiconductor device generally includes a memory cell array 120 consisting of a plurality of repeated cell units, a bit line amplifier 130 for amplifying a voltage difference between a bit line BL voltage and a complementary bit line /BL voltage of the memory cell array 120, switching devices MN1 and MN2 for electrically connecting a data line DL and a complementary data line /DL to the bit line BL and the complementary bit line /BL respectively, and a write driver 140 for supplying a write data voltage to the data line DL and the complementary data line /DL.

The bit line BL and memory cells in the memory cell array 120 are electrically activated when a word line is activated by a word line signal WL, and accordingly, a write data voltage supplied from the write driver 140 is written into the memory cells via the bit line BL.

The bit line amplifier 130 amplifies the voltage difference between the bit line BL voltage and the complementary bit line /BL voltage and supplies the amplified voltage to the bit line BL when the write data voltage supplied from the write driver 140 is applied to the bit line BL.

The switching devices MN1 and MN2, which are activated by a column selection line signal CSL, electrically connect the data line DL and the complementary data line /DL to the bit line BL and the complementary bit line /BL, respectively.

The write driver 140, which is activated by a write enable signal PWR, supplies the write data DIN voltage supplied thereto to the data line DL and the complementary data line /DL.

A column selection line enable signal PCSLE and disable signal PCSLD generator 10, which is activated by a master clock signal CLK and a write enable signal PWR, supplies a column selection line enable signal PCSLE and a column selection line disable signal PCSLD to a main decoder 60.

A command signal controller 20 receives a command signal CMD and supplies a low

master signal PR to a word line driver 30. In addition, this controller generates the write enable signal and is deactivated by a stop signal CNTSTOP of a column address burst counter.

The word line driver 30, which is activated by the low master signal PR, supplies the word line signal to the memory cell array 120.

5       A column address buffer 40, which is activated by the master clock signal CLK, a column address set signal CASET and an inverted column address set signal CASETB and is reset by the stop signal CNTSTOP of the column address burst counter, receives an external address signal ADDR and an internal address signal PCAi and supplies a column address signal CAi to a pre-decoder 50.

10       The pre-decoder 50 receives the column address signal CAi and supplies a column address selection signal DCAij to the main decoder 60.

The main decoder 60, which is activated by the column selection line enable signal PCSLE and is deactivated by the column selection line disable signal PCSLD, receives the column address selection signal DCAij and generates the column selection line signal CSL.

15       A column address set signal CASET generator 70 receives the write enable signal PWR and generates the column address set signal CASET and the inverted column address set signal CASETB.

A column address counter 80, which is activated by the master clock signal CLK and the write enable signal PWR, generates the internal column address signal PCAi.

20       The column address burst counter 90, which is activated by the master clock signal CLK and the write enable signal PWR, supplies a third column address burst counter output signal CNT2 to a counter controller 100.

The counter controller 100 receives the third column address burst counter output signal CNT2 and generates the stop signal CNTSTOP of the column address burst counter.

25       In the conventional semiconductor device as constructed above, during the write recovery time ( $t_{WR}$ ), since the column selection line signal CSL is deactivated and the switching devices MN1 and MN2 are also deactivated if the write driver applies the last write data voltage to the bit line BL, the bit line BL and the complementary bit line /BL are

electrically isolated from the data line DL and the complementary data line /DL, respectively.

Therefore, during the write recovery time ( $t_{WR}$ ), the last write data voltage applied to the bit line BL is applied to the memory cells of the memory cell array 120 only by the bit line amplifier 130.

5        In addition, as the word line signal WL is deactivated by a pre-charge signal PRE, the word line and the memory cells of the memory cell array 120 are electrically isolated from each other. At this time, the voltage of the bit line BL is determined to be the voltage of the memory cells of the memory cell array 120.

FIG. 2 is a circuit diagram of the counter controller of the conventional semiconductor  
10        device. As shown in FIG. 2, the counter controller 100 always generates the stop signal CNTSTOP of the column address burst counter through an AND operation of an AND logic gate 107 with respect to the third column address burst counter output signal CNT2 and a power supply voltage signal VDD, regardless of a value of the write recovery time ( $t_{WR}$ ). FIG. 2 shows an operation circuit in the case that the length of data burst is 4.

15        FIG. 3 is a timing diagram showing a write operation of the conventional semiconductor device (in the case of  $t_{WR}=2$  clocks). In general, as shown in FIG. 3, when an activation command signal and an external address signal ADDR are input at C2 of the master clock signal CLK, the semiconductor device sets to be activated and the word line signal WL corresponding to the external address signal is activated. The word line signal  
20        WL is deactivated by the pre-charge command signal PRE.

When a write command signal WRITE and the external address signal ADDR are input at C4 of the master clock signal CLK, the column address signal CA<sub>i</sub> (Y0) into which first data D0 are written is activated. When the write command signal WRITE is input, the write enable signal PWR is activated, and accordingly, the column address set signal CASET is  
25        activated.

Column address burst counter output signals CNT0, CNT1 and CNT2 are activated by the write enable signal PWR. The first column address burst counter output signal CNT0 is activated by counting the master clock signal CLK, the second column address burst counter

output signal CNT1 is activated by counting the first column address burst counter output signal CNT0, and the third column address burst counter output signal CNT2 is activated by counting the second column address burst counter output signal CNT1.

After the column address signal CA<sub>i</sub> (Y<sub>0</sub>) into which the first data D<sub>0</sub> is written is activated, next column address signals Y<sub>1</sub>, Y<sub>2</sub> and Y<sub>3</sub> are activated by the column address burst counter output signals CNT<sub>0</sub>, CNT<sub>1</sub> and CNT<sub>2</sub>.

The stop signal CNTSTOP of the column address burst counter is activated by the third column address burst counter output signal CNT<sub>2</sub>, and accordingly the write enable signal PWR is deactivated.

The column selection line enable signal PCSLE and the column selection line disable signal PCSLD are activated by the write enable signal PWR, and the column selection line signal CSL is activated by the column selection line enable signal PCSLE and is deactivated by the column selection line disable signal PCSLD.

In the conventional semiconductor device, during the write recovery time (t<sub>WR</sub>), when the last data D<sub>3</sub> are transferred to the bit line BL through the column selection line signal CSL, the column selection line signal CSL is deactivated, and accordingly the bit line BL and the data line DL are electrically isolated from each other.

FIG. 4 is a block diagram illustrating a semiconductor device according to an embodiment of the present invention, where same reference numerals are given to same parts as FIGS. 1 to 3, the detailed description of which will not be repeated for the sake of simplicity.

A write recovery time (t<sub>WR</sub>) enable signal generator 300 supplies write recovery time (t<sub>WR</sub>) enable signals PtWR<sub>1</sub>, PtWR<sub>2</sub> and PtWR<sub>3</sub> to the counter controller 200 based on the value of the corresponding write recovery time (t<sub>WR</sub>).

The counter controller 200 provides the stop signal CNTSTOP of the column address burst counter through an AND operation with respect to the column address burst counter output signals CNT<sub>0</sub>, CNT<sub>1</sub> and CNT<sub>2</sub> and corresponding write recovery time (t<sub>WR</sub>) enable signals PtWR<sub>1</sub>, PtWR<sub>2</sub> and PtWR<sub>3</sub>. The stop signal CNTSTOP of the column address burst

counter is delayed in proportion to a value of the write recovery time (tWR). Accordingly, the command signal controller continues to generate the write enable signal PWR during the write recovery time (tWR).

5 The column address counter 80, which is activated by the master clock signal CLK and the write enable signal PWR, supplies the internal column address signal PCAi to the column address buffer 40. The column address counter 80 continues to generate the last signal of the internal column address signal PCAi for one or more cycles of the master clock signal CLK during the write recovery time (tWR). Accordingly, the column address buffer 40 continues to generate the last column address signal CAi for one or more clocks of the master clock  
10 signal CLK during the write recovery time (tWR).

Therefore, the main decoder 60 generates the last column selection line signal CSL3 during the write recovery time (tWR).

Compared to the conventional semiconductor device where the bit line BL voltage is supplied only by the bit line amplifier 130 during the write recovery time (tWR), the bit line  
15 BL voltage is supplied by the write driver 140 by repeatedly supplying the column selection line signal CSL during the write recovery time (tWR) in the semiconductor device according to the embodiment of the present invention.

Particularly, the write data voltage can be more effectively secured in the case that the last write data conflict with stored data.

20 FIG. 5 is a circuit diagram illustrating an enable and disable signal generator for a column selection line signal in a semiconductor device according to an embodiment of the present invention. As shown in FIG. 5, the column selection line enable signal PCSLE is generated by an AND operation of an AND gate 11 with respect to the write enable signal PWR and the clock signal CLK.

25 As shown in FIG. 5, the column selection line disable signal PCSLD is generated by an AND operation of an AND gate 13 with respect to the master clock signal CLK after a predetermined delay time and the write enable signal PWR activated by an inverted signal of the master clock signal CLK..

In this way, since the column selection line disable signal PCSLD is generated from the write enable signal PWR activated by the inverted signal of the master clock signal CLK, it can be generated with a delay later, compared to the column selection line enable signal PCSLE.

5        The column selection line disable signal PCSLD is preferably generated after being delayed by at least a half (1/2) of a period of the column selection line enable signal PCSLE, compared to the column selection line enable signal PCSLE.

FIG. 6 is a circuit diagram illustrating a command signal controller in a semiconductor device according to an embodiment of the present invention. The command signal controller  
10    20, which is activated by a write command signal PWRITE defining a write operation in a command decoder 21 among command signals externally input and is deactivated by the stop signal CNTSTOP of the column address burst counter, generates the write enable signal PWR.

Also, the command decoder 21 generates a low master signal PR to activate a word line driver 30.

15        As shown in FIG. 6, a signal generator for generating the write enable signal PWR can be configured to include a first NOR gate 22 into which the write command signal PWRITE is input, a second NOR gate 23 connected to the first NOR gate via a latch and into which the stop signal CNTSTOP of the column address burst counter is input, and an inverter 24 connected to an output terminal of the first NOR gate.

20        FIG. 7 is a circuit diagram illustrating a column address buffer in a semiconductor device according to an embodiment of the present invention. As shown in FIG. 7, the column address buffer 40, which is reset by the stop signal CNTSTOP of the column address burst counter and is activated by the column address set signal CASET, generates the column address signal CA<sub>i</sub> as the external address signal ADDR is transferred via a buffer after a  
25    predetermined delay time.

After the column address buffer 40 generates the column address signal CA<sub>i</sub> by means of the external address signal ADDR, it is activated by a signal derived from an AND operation of an AND gate 47 with respect to the master clock signal CLK and an inverted

signal of the column address signal CASET and generates the column address signal CAi as the internal column address signal PCAi is transferred.

FIG. 8 is a circuit diagram illustrating a main decoder in a semiconductor device according to an embodiment of the present invention. The main decoder 60, which is  
5 activated by a signal derived from an AND operation of an AND gate 61 with respect to the column selection line enable signal PCSLE and a column address selection signal DCAij activated by the column address signal CAi and is deactivated by the column selection line disable signal PCSLD, generates the column selection line signal CSL.

As shown in FIG. 8, the main decoder 60 includes a first PMOS transistor 63 into  
10 which a signal derived from an AND operation of an AND gate 61 with respect to the column selection line enable signal PCSLE and the column address selection signal DCAij is input, an NMOS transistor 65 into which the signal derived from the AND operation of the AND gate 61 with respect to the column selection line enable signal PCSLE and the column address selection signal DCAij is input, a second PMOS transistor 64 connected between the first  
15 PMOS transistor 63 and the NMOS transistor 65 and into which an inverted signal of the column selection line disable signal PCSLD is input, and an inverter 66 connected to a point between the second PMOS transistor 64 and the NMOS transistor 65.

When the column selection line enable signal PCSLE and the column address selection signal DCAij are both high, the signal derived from the AND operation for them becomes high,  
20 and accordingly the first PMOS transistor 63 turns off and the NMOS transistor 65 turns on. Accordingly, as the input of the inverter 66 remains low, the column selection line signal CSL is activated.

When the column selection line disable signal PCSLD is high, a low signal as an inverted signal is input into the second PMOS transistor 64, and accordingly the second PMOS  
25 transistor 64 turns on. Accordingly, as the input of the inverter 66 remains high, the column selection line signal CSL is deactivated.

As the column selection line disable signal PCSLD is activated by the write enable signal PWR enabled by the inverted signal of the master clock signal CLK, it can be generated

with a delay compared to the column selection line enable signal PCSLE.

Then, the column selection line signal CSL can be deactivated by the column selection line disable signal PCSLD after the column selection line signal CSL is activated by the column selection line enable signal PCSLE.

5 As described above, the column selection line disable signal PCSLD is preferably generated after being delayed by at least a half ( $1/2$ ) of the period of the column selection line enable signal PCSLE, compared to the column selection line enable signal PCSLE.

As charges are shared at a connection point between the second PMOS transistor 64 and the NMOS transistor 65 by further connecting the inverter 66 to a second inverter 67 via a  
10 latch, the column selection line signal CSL can be prevented from floating, a condition in which the logic state of the signal cannot be determined.

Since the second inverter 67 latches the column selection line signal CSL, widths of a PMOS transistor and an NMOS transistor constructing the second inverter 67 are preferably designed to be smaller than those in the inverter 66 for facilitating transition of the column  
15 selection line signal CSL.

The column address selection signal DCA<sub>ij</sub>, which is a signal decoded via the pre-decoder 50, has column address information required to select one of a plurality of column lines.

FIG. 9 is a circuit diagram illustrating a column address set signal CASET generator in  
20 a semiconductor device according to an embodiment of the present invention. The column address set signal CASET is activated by the write enable signal PWR and is deactivated after a predetermined delay time.

As shown in FIG. 9, the column address set signal CASET generator 70 generates the column address set signal CASET through an AND operation of an AND gate 74 with respect  
25 to the write enable signal PWR and an output signal from three inverters 71, 72 and 73 in series (a chain of inverters) into which the write enable signal PWR is input.

When the write enable signal PWR is activated, since the output signal from the chain of inverters 71, 72 and 73 is deactivated after a predetermined delay time, the column address

set signal CASET is activated during the delay time.

Since the delay time of the write enable signal PWR increases in proportion to the number of inverters in the chain of inverters 71, 72 and 73, the column address set signal CASET generator 70 can adjust a time when the column address set signal CASET is activated by adjusting the number of inverters in the chain of inverters 71, 72 and 73.

Only when the number of inverters in the chain of inverters 71, 72 and 73 is odd, the column address set signal CASET can be deactivated after the predetermined delay time.

FIG. 10 is a circuit diagram illustrating a counter controller in a semiconductor device according to an embodiment of the present invention. As shown in FIG. 10, the counter controller 200 generates the stop signal CNTSTOP of the column address burst counter through an AND operation of an AND gate 205 with respect to the third column address burst counter output signal CNT2 and a corresponding write recovery time (tWR) enable signal tWR1 in the case that the write recovery time (tWR) is 1 (one clock).

The counter controller 200 generates the stop signal CNTSTOP of the column address burst counter through an AND operation of an AND gate 202 with respect to a signal derived from an AND operation of an AND gate 201 with respect to the first column address burst counter output signal CNT0 and the third column address burst counter output signal CNT2 and a corresponding write recovery time enable signal tWR2 in the case that the write recovery time (tWR) is 2 (two clocks), and generates the stop signal CNTSTOP of the column address burst counter through an AND operation of an AND gate 204 with respect to a signal derived from an AND operation of an AND gate 203 with respect to the second column address burst counter output signal CNT1 and the third column address burst counter output signal CNT2 and a corresponding write recovery time enable signal tWR3 in the case that the write recovery time (tWR) is 3 (three clocks).

The column address burst counter output signals CNT0, CNT1 and CNT2 are activated by the write enable signal PWR. The first column address burst counter output signal CNT0 is generated by counting the master clock signal CLK, the second column address burst counter output signal CNT1 is generated by counting the first column address burst counter

output signal CNT0, and the third column address burst counter output signal CNT2 is generated by counting the second column address burst counter output signal CNT1.

Accordingly, the second column address burst counter output signal CNT1 is generated with a delay by one clock of the master clock signal CLK, compared to the first column address burst counter output signal CNT0, and a generation period of the signal CNT1 is two times that of the first column address burst counter output signal CNT0.

Similarly, the third column address burst counter output signal CNT2 is generated with a delay by one clock of the master clock signal CLK, compared to the second column address burst counter output signal CNT1, and a generation period of the signal CNT2 is two times that of the second column address burst counter output signal CNT1.

Accordingly, in the case that the write recovery time (tWR) is 2 (two clocks), the stop signal CNTSTOP of the column address burst counter is generated with a delay by one clock of the master clock signal CLK, compared to the case that the write recovery time (tWR) is 1 (one clock), and in the case that the write recovery time (tWR) is 3 (three clocks), the stop signal CNTSTOP of the column address burst counter is generated with a delay by one clock of the master clock signal CLK, compared to the case that the write recovery time (tWR) is 2 (two clocks).

In a similar way, in the counter controller 200, a fourth column address burst counter output signal is generated with a delay by one clock of the master clock signal CLK, compared to the third column address burst counter output signal CNT2, and has two times a generation period of the third column address burst counter output signal CNT2. Also, the stop signal CNTSTOP of the column address burst counter is generated through an AND operation of an AND gate with respect to a signal derived from an AND operation of an AND gate with the fourth column address burst counter output signal and the third column address burst counter output signal CNT2, and a corresponding write address time enable signal tWR4. Accordingly, in the case that the write recovery time (tWR) is 4 (four clocks), a generation time of the stop signal CNTSTOP of the column address burst counter can be delayed by one clock of the master clock signal CLK, compared to the case that the write recovery time (tWR)

is 3 (three clocks).

In this way, the counter controller 200 can generate the stop signal CNTSTOP of the column address burst counter with a delay by the clocking number of the master clock signal CLK in proportion to values of a plurality of write recovery time (tWR).

FIG. 11 is a circuit diagram of a write recovery time enable signal generator in a semiconductor device according to an embodiment of the present invention. By constructing the write recovery time enable signal generator 300 as many as the number of kinds relative to values of the write recovery time (tWR), a desired value of the write recovery time (tWR) can be set.

As shown in FIG. 11, the write recovery time enable signal generator 300 includes a PMOS transistor 302 into which an inverted signal of a write recovery time determination signal POWER\_UP is input, an NMOS transistor 304 into which the inverted signal of a write recovery time determination signal POWER\_UP is input, a fuse 303 connected between the PMOS transistor 302 and the NMOS transistor 304 for electrically isolating the NMOS transistor 302 from the NMOS transistor 304 if necessary, and an inverter 305 connected to a point between the fuse 303 and the NMOS transistor 304.

In the write recovery time enable signal generator 300, when the write recovery time determination signal POWER\_UP is low, its inverted signal is high, and accordingly the PMOS transistor 302 turns off and the NMOS transistor 304 turns on. Accordingly, since an input of the inverter 305 keeps low, the write recovery time enable signals PtWR1, PtWR2 and PtWR3 are activated.

On the other hand, in the write recovery time enable signal generator 300, when the write recovery time determination signal POWER\_UP is high, its inverted signal is low, and accordingly the PMOS transistor 302 turns on and the NMOS transistor 304 turns off. Accordingly, since the input of the inverter 305 remains high, the write recovery time enable signals PtWR1, PtWR2 and PtWR3 are deactivated.

As charges are shared at a connection point between the fuse 303 and the NMOS transistor 304 by further connecting the inverter 305 to a second inverter 306 via a latch, the

write recovery time enable signals PtWR1, PtWR2 and PtWR3 can be prevented from floating, a condition in which the logic state of the signal cannot be determined.

Since the second inverter 306 latches the write recovery time enable signals PtWR1, PtWR2 and PtWR3, widths of a PMOS transistor and an NMOS transistor constructing the second inverter 306 are preferably designed to be smaller than those in the inverter 305 for facilitating transition of the write recovery time enable signals PtWR1, PtWR2 and PtWR3.

The write recovery time enable signal generator 300 changes the write recovery time determination signal POWER\_UP from low to high and keeps the signal POWER\_UP high under a state that one fuse 303 corresponding to a value of the write recovery time is cut off and the other fuses 303 remain unchanged.

Accordingly, in the case that the fuse 303 is cut off, as the input of the inverter 305 becomes low under a state where the write recovery time determination signal POWER\_UP is low, the write recovery time enable signals PtWR1, PtWR2 and PtWR3 are activated. At this time, even if the write recovery time determination signal POWER\_UP changes into a high state, since the fuser 303 electrically isolate the PMOS transistor 302 from the NMOS transistor 304, the input of the inverter 305 remains low and the write recovery time enable signals PtWR1, PtWR2 and PtWR3 remain activated.

On the other hand, in the case that the fuse 303 is not cut off, as the input of the inverter 305 becomes low under a state where the write recovery time determination signal POWER\_UP is low, the write recovery time enable signals PtWR1, PtWR2 and PtWR3 are activated. However, if the write recovery time determination signal POWER\_UP is changed into a high state, since the PMOS transistor 302 and the NMOS transistor 304 are electrically connected to each other and accordingly the input of the inverter 305 is changed in a high state, the write recovery time enable signals PtWR1, PtWR2 and PtWR3 are deactivated.

FIG. 12 is a timing diagram showing a write operation of a semiconductor device (in the case of  $t_{WR}=2$  clocks) according to an embodiment of the present invention. As shown in FIG. 12, when the activation command signal and the external address signal ADDR are input at C2 of the master clock signal CLK, the semiconductor device according to the

embodiment of the present invention sets to be activated and the word line signal WL corresponding to the external address signal is activated. The word line signal WL is deactivated by the pre-charge command signal PRE.

5 When the write command signal WRITE and the external address signal ADDR are input at C4 of the master clock signal CLK, the column address signal CA<sub>i</sub> into which first data are written is activated. When the write command signal WRITE is input, the write enable signal PWR is activated, and accordingly the column address set signal CASET is activated.

10 The column address burst counter output signals CNT0, CNT1 and CNT2 are activated by the write enable signal PWR. The first column address burst counter output signal CNT0 is activated by counting the master clock signal CLK, the second column address burst counter output signal CNT1 is activated by counting the first column address burst counter output signal CNT0, and the third column address burst counter output signal CNT2 is activated by counting the second column address burst counter output signal CNT1.

15 After the column address signal CA<sub>i</sub> into which the first data is written is activated, next column address signals CA<sub>i</sub> are activated by the column address burst counter output signals.

20 The stop signal CNTSTOP of the column address burst counter is activated by a signal derived from an AND operation of an AND gate with respect to the third column address burst counter output signal CNT2 and the first column address burst counter output signal CNT0, and accordingly the write enable signal PWR is deactivated.

25 The column selection line enable signal PCSLE and the column selection line disable signal PCSLD are activated by the write enable signal PWR, and the column selection line signal CSL is activated by the column selection line enable signal PCSLE and is deactivated by the column selection line disable signal PCSLD.

According to the present invention described above, by repeatedly activating only the column line into which the last data are written during a write recovery time (t<sub>WR</sub>), the last data voltage can be sufficiently supplied to memory cell arrays, and in addition, the time when

a column line into which the last data are written is activated can be adjusted based on the value of the write recovery time (tWR).

Although the present invention has been described in connection with the preferred embodiments of the present invention, it is not limited thereto. It will be apparent to those  
5 skilled in the art that various modifications and changes may be made thereto without departing from the scope and spirit of the invention.